SENSING AND MODELLING MECHANICAL PROPERTIES OF FRUITS FOR QUALITY

Margarita Ruiz-Altisent, Prof., Pilar Barreiro, Ass. Researcher
Dept Rural Engineering, ETSIA, UPM, 28040 Madrid (Spain)

Introduction

Nondestructive techniques are extensively researched for the measurement of physical properties of fruits related to quality. Optical properties can be applied mainly in the detection of those quality features which are related to the chemical composition of the fruit, color (in the VIS region) or chemical constituents (sugar, in the NIR region) being the most important.

The most relevant mechanical property of fruits is consistency, generally called firmness, and to date only techniques which are able to measure the mechanical properties of the fruit bulk tissue are used for its prediction. Fruits can be modelled as elastic bodies, or at least as partially elastic. Therefore, the measurement of some elastic constants of the fruit can be used for the evaluation of its firmness. The differences in the response to loading are relevant in studying a) fruit firmness and b) bruising susceptibility. Both have been modelled for selected fruit species and varieties.

Nondestructive testing of firmness

Two distinct basic techniques are used:

1. The response to small-energy impacts: it permits the evaluation of the elastic and plastic relative behaviors of the fruit. Force response during contact of a rigid spherical mass impacting onto a fruit is governed by the impactor's mass and radius of curvature and by the impact velocity; further, it is governed by the deformation properties of the fruit, which in turn relate closely to its elastic properties. A procedure for measuring firmness evolution during shelf life in **pears** and **apples** has been developed (Jarén and Ruiz-Altisent, 1992; Ruiz-Altisent *et al*, 1994). Small variations in height of drop (due to fruit size variation) and possible bruise caused by the impact were closely studied, and the results showed that they do not constrain the application of the technique. Damage was negligible using the appropriate impactor. The procedure has also been tested in **melons, avocadoes, peaches, apricots, nectarines**, with good results.

At harvest, fruit damage susceptibility (**apples and pears**) is influenced mainly by firmness and by fruit turgidity (García *et al* 1995;Verstraeken *et al* 1995). Acceptability or rejectability of fruit (**apples, pears, peaches and apricots**) due to bruising was modelled with accuracy using neural networks (Barreiro *et al* 1995). Explicative variables were firmness, loading level (in impact and in compression) and storage treatment. Simulation applied to all the tested species and varieties showed the allowable impact or compression loads applied to fruits during harvesting and handling, without risking bruising above the EC limits for Class I.

2. The response to mechanical vibration (created by a small impact) measured by sonic resonance; the vibrational characteristics of materials are related to their elastic properties. Modulus of elasticity and damping factor are the main properties governing the natural and the resonance frequencies of materials. In the vibration response of whole fruits the resonance frequencies are manifold, related to the different vibration modes. Some of the resonance frequencies of apples are related to its firmness, especially when used in the "stiffness factor": $f^2m^{2/3}$. The selection of the order number of f (resonance frequency) best representing the "bulk" vibration of the fruit has taken some

effort, and different solutions have been used with good results. The second f has been chosen in the device developed for grading fruits for firmness (Chen *et al* 1993) . The procedure has been successfully applied to measurement of firmness in **apples, peaches, pears, tomatoes, apricots.** In most cases, three measurements per fruit are necessary to obtain good repeatability. At the present state, a portable device has been extensively tested, also in comparison with the rest of firmness sensing devices included in the mentioned cooperative CAMAR project (Various authors, 1995). Further possible techniques for sensing firmness have been researched, in all cases related either to the direct measurement of elastic properties or, otherwise, to the evaluation of structural characteristics of fruit/plant tissues.

Comparison of different destructive and nondestructive firmness testers

Magness-Taylor (M-T) firmness has been used extensively as a standard for comparison of firmness prediction. There is a fundamental problem in selecting the means of comparison of different sensors, as M-T is known to be highly unreliable and with low repeatability for different fruits in widely varying firmness states. A comparison of nondestructive sensors with destructive M-T was carried out (Steinmetz *et al* 1955). Possible procedures for comparing sensors outputs are:

a) correlation and regression, and other statistical comparisons

b) precision of the classification of fruits into firmness classes.

The combination (called fusion) of different firmness sensors (as well as sensors for other quality properties) is able to improve classification and hence fruit grading precision. It also shows that for these fruits, nondestructive sensors are able to classify fruits in preestablished firmness classes with an accuracy that is at least similar to that defined by M-T.

References

Barreiro P., V. Steinmetz, M. Ruiz-Altisent. 1995. Neural bruise prediction models for fruit handling and machinery evaluation. 1st IFAC/CIGR/EURAGENG/ISHS workshop on Control Applications in Post-Harvest and Processing Technology. CAPPT'95:183-192.

Chen H., De Baerdemaeker J., Vervaeke F. 1993. Acoustic impulse response of apples for monitoring texture change after harvest. Agricultural Engineering and Rural Development. IV: 30-38.

García J.L., M. Ruiz-Altisent y P. Barreiro. 1995. Factors influencing apple and pear physical properties and bruise susceptibility. J.Agric.Eng.Res. (in press); AGENG Paper 94-G-062 Milano.

Jarén C., M. Ruiz-Altisent. 1992. Sensing physical stage of fruits by their response to non-destructive impacts. AGENG '92. Paper no. 9211 113 (Uppsala).

Ruiz-Altisent M., C. Jarén, P. Correa. 1994. Fruit quality sensing: Post-harvest ripeness. In: "Fruit Nut and Vegetable Production Engineering". Vol II: 209-220. Editor F.Juste (IVIA) Published by M° Agricultura, INIA Madrid. ISBN 84-7498-435-1.

Steinmetz V., M. Crochon, V. Bellon-Maurel, J.L. García, P. Barreiro, L. Verstraeken. 1995. Sensors for fruit firmness assessment: Comparison and fusion. J. Agric. Eng. Res.(in pr.)

Various authors: CAMAR CT91-0206, Final report 1995: Quality of fruits: Engineering research for improving the quality preservation during pre and postharvest operations. DG VI. CE Brussels.

Verstraeken E., J.L. García, M. Ruiz-Altisent, J. De Baerdemaeker. 1995. Controlling moisture loss as a tool to reduce bruise susceptibility. !er IFAC/CIGR/EURAGENG/ ISHS workshop on Control Applications in Post-Harvest and Processing Technology. CAPPT'95. pgs.215-222. Ostend, Belgium.